Space Technology Research Grants

Computational Design of an Additive Manufacturing Process to Produce Tailorable, Multifunctional Gradient Alloys

Completed Technology Project (2014 - 2016)

Project Introduction

Lightweight, multifunctional structural materials technology has been identified as a critical strategic need by NASA and is the highest-priority materials challenge identified by the National Research Council. Additive manufacturing (AM) methods such as laser engineered net shaping (LENS) have unlocked new possibilities for materials design, enabling unprecedented control over the design of bulk materials at the microstructural level and raising the prospect of designing new materials literally from the ground up. This is particularly promising for the novel engineering trade-offs made possible by gradient alloys. A gradient alloy is a material that has a composition that varies continuously along one or more directions. These materials enable the physical properties of a component to be spatially optimized for multiple service functions. The lack of sharp interfaces created by traditional joining operations reduces stress concentrations that could lead to failure. Designing new gradient alloys is a haphazard process for the same reason that the joining of dissimilar metals by laser welding proves challenging, namely the prevalence of brittle intermetallic phases in the intermediate compositions of many desirable gradients such as Fe-Ti, Al-Ti and Al-Fe. CALPHAD-based thermodynamic and kinetic models can be used to project arbitrary paths in phase space for systems with any number of components. When the processing conditions are controlled, phase diagrams become maps for navigating the composition design space of gradient alloys. The purpose of this work is to develop a software-based design tool, based on computational thermodynamics and kinetics, for determining optimal thermal processing conditions for producing gradient alloys by additive manufacturing. Because of the prevalence of a requirement to join the two alloys in structural applications, the design of a stainless steel to aluminum gradient alloy will be initially considered. The proposed work will provide an open software framework for the design of gradient alloys by laser-based additive manufacturing methods. Experimental studies of the thermodynamics and transformation kinetics of stainless steel and aluminum will be used to validate the results of theoretical calculations. Finally, the most promising candidate gradient path will be used to make processing recommendations for a prototype stainless steel to aluminum gradient alloy.

Anticipated Benefits

The proposed work will provide an open software framework for the design of gradient alloys by laser-based additive manufacturing methods. Lightweight, multifunctional structural materials technology has been identified as a critical strategic need by NASA and is the highest-priority materials challenge identified by the National Research Council. Additive manufacturing (AM) methods such as laser engineered net shaping (LENS) have unlocked new possibilities for materials design, enabling unprecedented control over the design of bulk materials at the microstructural level and raising the prospect of designing new materials literally from the ground up. This is particularly

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Organizational Responsibility

Responsible Mission Directorate:

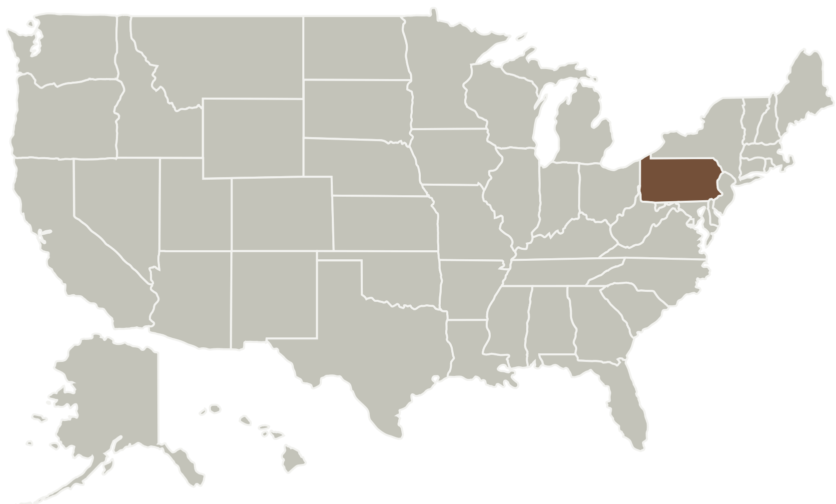
Space Technology Mission Directorate (STMD)

Responsible Program:

Space Technology Research Grants

promising for the novel engineering trade-offs made possible by gradient alloys.

Primary U.S. Work Locations and Key Partners



Primary U.S. Work Locations
Pennsylvania

Project Website:

https://www.nasa.gov/directorates/spacetech/home/index.html

Project Management

Program Director:
Claudia M Meyer

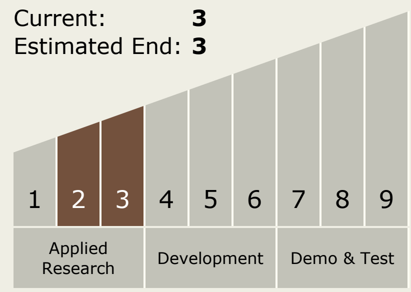
Program Manager:
Hung D Nguyen

Principal Investigator:
Zi-kui Liu

Co-Investigator:
Richard A Otis

Technology Maturity (TRL)

Start: **2**
Current: **3**
Estimated End: **3**



Technology Areas

Primary:

- TX02 Flight Computing and Avionics
  - └ TX02.3 Avionics Tools, Models, and Analysis
    - └ TX02.3.4 Electromagnetic Environment Effects

Target Destination
Mars